

EXTRA DIMENSIONS

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LECTURE 3

MODIFY GAUGE KK PROFILE

Extra dimension does *not* have analog of GIM factor:

coupling to gauge KK (in units of g_4), $a_{s,d} \sim O(1)$

and different

Better picture (Fig. 13): couplings to gauge KK $\ll 1 \rightarrow$

FCNC suppressed (even if non-universal)

How to modify KK decomposition?

BRANE KINETIC TERMS (I)

- Localized interactions at fixed points (branes):

Allowed (not on S^1) +

Generated by loops even if absent/zero at tree-level

(hep-ph/0012379, hep-ph/0204342)

$$\mathcal{L}_{5D} = -\frac{1}{4}[F_{MN}F^{MN} + \delta(y)rF_{\mu\nu}F^{\mu\nu}] + \bar{\Psi}(\partial_M + g_5 A_M)\Gamma^M\Psi \quad (1)$$

Dimensional analysis: $[A_M] = 3/2$, $[\Psi] = 2$, $[g_5] = -1/2$

- Brane kinetic term has dimension -1 (length)

BRANE KINETIC TERMS (II)

Different normalization for A_M : $A_M \rightarrow \hat{A}_M/g_5$

$$\mathcal{L}_{5D} = -\frac{1}{4}\left[\frac{1}{g_5^2}\hat{F}_{MN}\hat{F}^{MN} + \delta(y)\frac{r}{g_5^2}\hat{F}_{\mu\nu}\hat{F}^{\mu\nu}\right] + \bar{\Psi}\left(\partial_M + \hat{A}_M\right)\Gamma^M\Psi \quad (2)$$

$[\hat{A}_M] = 1$, brane kinetic term dimensionless (as in $4D$):

$$r/g_5^2 \equiv 1/g_{\text{brane}}^2$$

KK DECOMPOSITION WITH BRANE TERMS

Consider scalar for simplicity (gauge case is similar)

Summary (homework 2 and hep-ph/0207056 for details):

Orthonormality:

$$\int dy f_n^*(y) f_m(y) [1 + r\delta(y)] = \delta_{mn} \quad (3)$$

Differential equation:

$$[\partial_y^2 + m_n^2 + r\delta(y)m_n^2]f_n(y) = 0 \quad (4)$$

Solution is linear combination of sin, cos:

different one for $y = 0$ to $y = \pi R$ and

$y = -\pi R$ to $y = 0$

Use conditions such as continuity at $y = 0$,

matching discontinuity in derivative to $\delta(y)$ etc.

to solve for coefficients of sin, cos

COUPLING OF *ZERO*-MODE

Flat profile (only normalization affected by brane term):

$$g_4 = \frac{g_5}{\sqrt{r + 2\pi R}} \quad (5)$$

- For large brane kinetic terms,

$$g_4 \approx \frac{g_5}{\sqrt{r}} \quad (6)$$

COUPLINGS OF KK TO BRANES FOR LARGE BRANE KINETIC TERMS

- Coupling to particle (light fermion) localized at $y = 0$
suppressed (compared to zero-mode)

$$g_5 \times f_n(0) \sim g_4 / \sqrt{r/R}$$

- Coupling to particle (Higgs) localized at $y = \pi R$
enhanced

$$g_5 \times f_n(\pi R) \sim g_4 \times \sqrt{r/R}$$

Large brane kinetic terms repel gauge KK mode from
that brane

FCNC SUPPRESSED

- Similar suppression in coupling to gauge KK for exponential profiles of light fermions (peaked at $y = 0$):
 r/R provides analog of GIM suppression

New hierarchy: $r/R \gg 1$?

Not really: $O(10)$ enough

ELECTROWEAK PRECISION TESTS

1. 4-FERMION OPERATORS

Compare to SM Z exchange: $\sim g_Z^2/m_Z^2$

Data agrees with SM prediction at $\sim 0.1\%$ level

For $r = 0$ (no brane term):

Gauge KK coupling $\approx \sqrt{2}g_4$ for fermion at $y = 0$

(light fermions near $y = 0$)

$\rightarrow m_{KK} \gtrsim$ a few TeV

- Suppressed effect (by $\sim r/R$) for

large brane kinetic terms \rightarrow

$m_{KK} \sim$ TeV *easily* allowed